Salinity Signal for San Francisco Bay

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Introduction

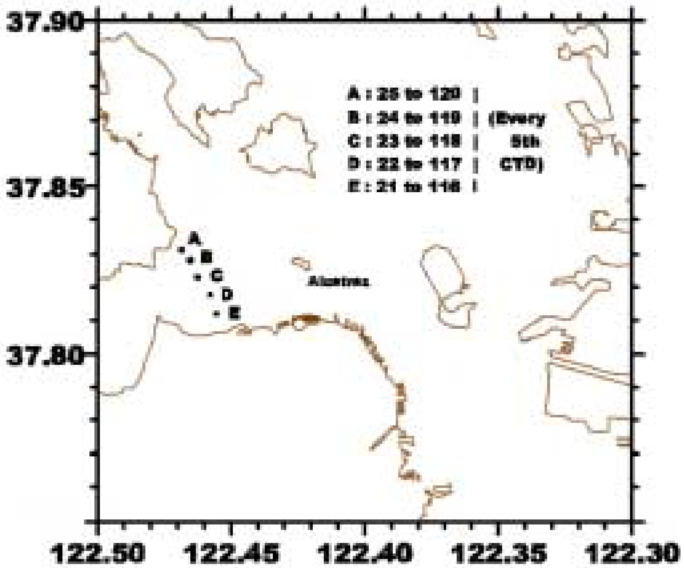
The second leg of the winter OC3570 (Operational Oceanography) cruise was initially planned for the Point Sur region but was switched to San Francisco Bay. This last minute alteration was decided upon to avoid heavy seas that would not support CTD operations during the short four-day cruise on 9-12 February 2001. While seeking shelter in San Francisco Bay, the Research Vessel Point Sur did undertake a continuous 27.5 hour CTD sampling from five stations just inside the Golden Gate Bridge.

Objective

The goal of this project was to analyze the CTD data and create a "movie" to estimate and visualize the salinity signal over a full tidal cycle. Similar projects were conducted by Noel Russnogle (Jan 1997) and Michael Rocheleau (Jan 1998.) Noel's salinity display consisted of a choppy 22 frame clip. Michael furthered Noel's approach and developed a smooth 161 frame movie that displayed the tidal signal. In this version of the salinity project, the movie has been altered to incorporate a later version of Matlab (version 5.3) and upgraded to allow for web display.

Data

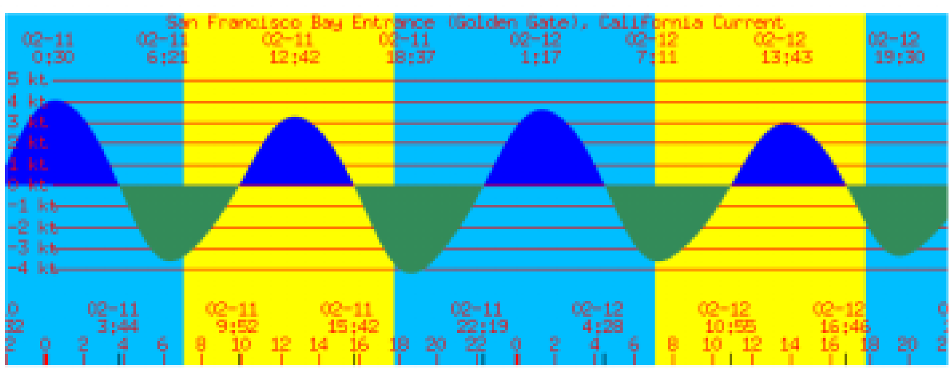
For 27.5 hours, the students and crew of the R/V Point Sur did continuous CTD sampling. Starting at 0030(PST) on the 11th of February a total of 100 CTD samples were gathered from five stations. The ship started with Station E (CTD a021) and continued in descending station order on a



continuous south-to-north leg. Previous student cruise operations were conducted on north-to-south and south-to-north legs. During this cruise, a constant descending station order was maintained. The were some minor breaks in the continuous sample rate to allow for shipping traffic, but these pauses were

San Francisco Bay Entrance (Golden Gate), California Current

11 February 2001 - 12 February 2001



infrequent and minimal in duration.

The first CTD station (a021) directly corresponds with the predicted max flood on 11 Feb 0030(PST.) As seen in the chart below, a complete tidal cycle was sampled during the 27.5 hour period. The final CTD sample (a120) was gathered at Station A on 12 Feb at 0400. This time was just prior to the slack water at 0428 and was chosen to support the return voyage of R/V Point Sur. The tidal chart vividly displays the tidal fluctuations, but does not clearly depict the exact velocities for each flood, ebb and slack water condition. A table has been included in the critical data section of this report to clearly display this information in tabular form.

All of the associated Matlab code for the salinity movie has been included as an attachment. Additionally, the Matlab code and salinity movie clip will be saved on the OC3570 class web site for future viewing and project manipulation.

Procedure

The procedure to read, separate, categorize and manipulate the salinity data into a movie can be described in five parts:

1. Data was read-in and separated by stations.
2. Data was cleansed to remove the ascending portion of the CTD cast and allow for a common beginning/ending depth for each station. Must achieve equal station depths as each CTD cast will not start and stop at the same location.
3. To overcome the unequal station separations and associated times between each station, a biharmonic regression was applied. This regression, provided by Professor Collins, resulted in a matrix of five coefficients for each measured level (see biharmonic regression discussion below.)
4. Since Matlab requires equal matrices for computations, each station was filled with the variable Not a Number (NaN) were data was missing.
5. Finally, the matrices were plotted using the contourf (contour fill) function and gathered into a 170 frame Matlab movie. This movie was transformed and saved as an mpeg file to allow for easier web viewing.

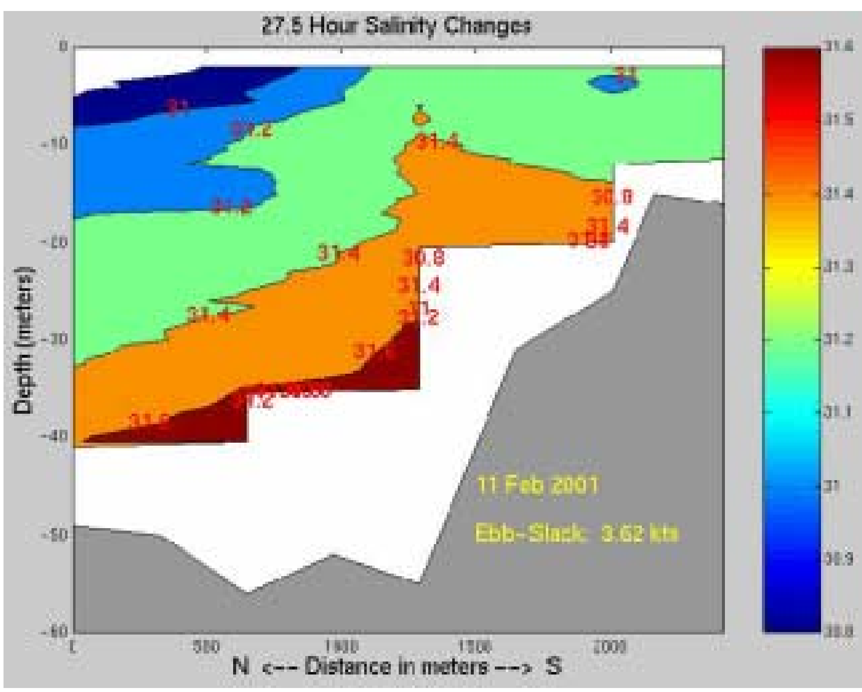
The biharmonic regression formula produced five coefficients for each level of each station. These coefficients were then used to produce the associated values for the increments between the data gaps. The formula used was (chosen frequencies were the semi-diurnal and diurnal tides):

$$X = c1 + c2*\cos(2*pi*t) + c3*\sin(2*pi*t) + c4*\cos(4*pi*t) + c5*\sin(4*pi*t)$$

c1 = mean
c2 & c3 = first harmonic
c4 & c5 = second harmonic
t = time (hours)

Results

The movie slides are arranged in a cross-section view of the Bay, with north (station A) on the left and south (station E) on the right of the page. The stair-step appearance of the bottom topography is due to the limited number of stations and their crude corresponding chart depths. A pop-up display of the tidal characteristics has been included to show the phase and strength of the tidal signal as the movie progresses. The 170 frame movie clearly represents the surging flood and ebb tidal variations as a function of time.



A stronger fresh water outflow was observed near station A and a more stagnant regime was witnessed near station E. The more saline waters were corrected displayed as a wedge of dense water approaching from the bottom of the movie in the vicinity of stations B & C. Finally, we see the largest concentrations of fresh (30.8 psu) and saline (32.0 psu) waters after the strongest ebb (-4.21 kts) and flood (4.05 kts) currents.

Initial analysis may lead the viewer to believe that the movie lags slightly behind the predicted tidal variations, but this is an expected phase lag. The ocean forcing will lag behind the maximum and minimum tidal variations. The expected salinity signal was in phase with the forecasted tidal currents for the Golden Gate Bridge. All in all, the movie portrays a good example of the salinity variations and associated complications with a tidally mixed estuary.

Recommendations

The movie was representative of the expected salinity signal and declared a success visual tool to display the tidal forcing in this region. Maybe future projects could be expanded to incorporate other principle components and show temporal fluctuations in the temperature and oxygen dynamics associated with the tidal regime. Maybe the ADCP data could be displayed in a movie environment.

For future projects, I would encourage the transformation of this Matlab code into a more current and widely accepted movie application. Additionally, I would challenge the next participant to devise a more accurate bottom topography profile for the survey region.

Critical Data

Station Distances:

A-B	649 m
B-C	640 m
C-D	722 m
D-E	411 m

Bottom Topography:

Station	Depth (m)	Distance (m)
A	49	0
Midpoint	50	325
B	56	649
Midpoint	52	969
C	55	1289
Midpoint	31	1650
D	25	2011
Midpoint	15	2166
E	16	2423

Predicted Currents:

Date	Time (PST)	Current (kts)	Classification
2-10-2001	21:32	0.01	Slack-Flood
2-11-2001	00:30	4.05	Max Flood
2-11-2001	03:44	0.00	Slack-Ebb
2-11-2001	06:21	-3.62	Max Ebb
2-11-2001	09:52	0.00	Slack-Flood
2-11-2001	12:42	3.26	Max Flood
2-11-2001	15:42	0.00	Slack-Ebb
2-11-2001	18:37	-4.21	Max Ebb
2-11-2001	22:19	0.01	Slack-Flood
2-12-2001	01:17	3.59	Max Flood
2-12-2001	04:28	-0.01	Slack-Ebb